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Affordable and middle-class housing on Johannesburg's mining sites: a benefit-cost analysis

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This paper examines the redevelopment of former gold mining land close to the downtown area of Johannesburg for affordable and middle-income housing. This could provide savings for out-of-pocket costs, time saving for commuting costs and better property appreciation. However, the properties may be costly to remediate and may still pose some health risks from exposure to radon. A cost–benefit analysis examined these issues from the perspective of the home occupant. The present value of the net benefits over a 20-year study period indicated very positive cost–benefit ratios, in excess of five units of benefit for each unit of cost, suggesting that the affordable and middle-income housing markets would see the area as desirable, could price the additional risk and would accept housing modified to reduce the potential health risks. The policy implications supported the release of former mining land for housing on a careful case-by-case basis.

1. INTRODUCTION

Over the past 12 years the South African government has been addressing one of the most sensitive issues the country has been facing: housing. It has managed to build close to two million units around the country. Gauteng Province and the City of Johannesburg are dealing with the same problem as the rest of the country. However, according to the Gauteng Housing Annual Report for 2001/2002, 'The location of the majority of new housing projects since 1994 has not had a positive impact on changing the apartheid structure of the cities – in most instances; the poorest communities of Gauteng remain increasingly marginalized'. It is not only the poorest who are affected but also the growing number of upper low-income and low middle-income earners. They are unable to afford the well-located, well-established neighbourhoods and affordable new locations are on the outskirts of the city.

According to the Minister of Housing, from 1994 to the end of 2006 the government built 2 148 658 subsidised housing units, but still needs to build 625 000 to meet the demand (Sisulu, 2006). Meanwhile, according to Charlton (2004), it is very difficult to close this gap, as there is a duplication of residence happening, with people renting a second room so they can live closer to the economic opportunity rather than in the peripheral subsidised housing they have obtained from the government.

Respectively, Professor, Levin College of Urban Affairs, Cleveland State University, Cleveland, Ohio, USA; and Senior Lecturer, School of Architecture and Planning, University of the Witwatersrand. The authors wish to thank iProp, a Johannesburg-based property company and PDNA, a professional services firm, for their financial contribution; NNR (the National Nuclear Regulator) and Andrew Barker for their time and effort; and François Viruly for his assistance in the project. They would also like to thank the Wits postgraduate class of Development Planning of TRPL 533 for carrying out the survey, in particular Hlengani Baloyi, David Mokoena, Nathan Venter and Nathi Radebe for their dedication to the project. Finally, they thank the Fulbright Program for bringing Professor Simons to South Africa. However, the authors received no funds from these grants, nor do they have any interest, financial or otherwise, in the development of housing sites resulting from the outcomes of this study.

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Sihlongonyane and Karam (2003:173) concluded that the mine dump land in the area north of Soweto and south of the Johannesburg Central Business District (CBD) was an important location for making an attempt to integrate the apartheid city and move the black population to 'convenient locations, closer to transport, jobs and urban facilities'. Figure 1 shows the location of the research area, which is part of the mine dump belt.

Given this need, the research allowed an opportunity to evaluate the benefits and costs of locating low- to moderate-priced housing on mining sites in Johannesburg while examining the costs of remediating the sites and the potential health and financial risks to the benefit of residents, the public sector, the municipality and private developers. Former mining sites (many in attractive locations, see Figure 1) are potentially negatively affected by radon and other contaminants (IDSP, 1987; De Beer, 1998). This research

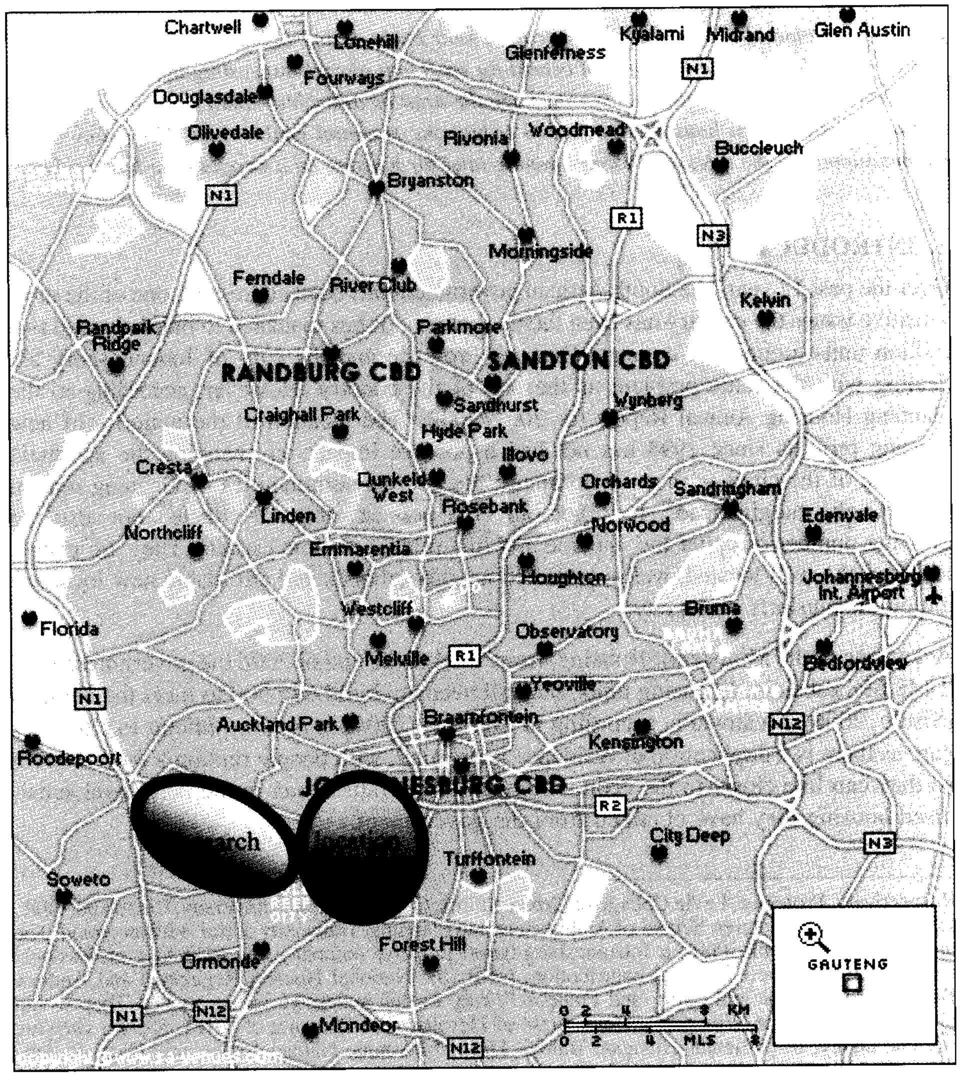

Figure 1: Location of mining lands in relation to Johannesburg CBD and Soweto
Source: South Africa Explored (no date).

is timely, since the National Nuclear Regulator is in the process of promulgating new regulations for developing this type of property, relying in part on the US Environmental Protection Agency and other international standards and experiences.

The benefits and costs of housing location have been previously studied in eThekwini (Durban, South Africa) from the perspective of government expenditure on housing and transport (Aucamp & Moodley, 2002). The results showed very substantial benefits for well-located subsidised housing, compared with remote locations. This research takes a similar approach, but viewing the benefits and costs from the perspective of the housing occupant and modelling the results using net present value.

Risks are part of economic life and, in the case of mine dump land, there are several types of risks in play: (1) the potential health risks to residents, (2) the opportunity costs to society of not using potentially desirable land, which forces housing further to the periphery away from the urban core and (3) the related job opportunities and social unrest arising from unmet expectations. Using these sites for housing, while not a perfect risk-free solution, would also help integrate the city (Sihlongonyane & Karam, 2003). The aim of this study, based on academic literature, personal surveys of Soweto residents and other persons living in Johannesburg and property market and environmental cost data, was to determine potential courses of action for policy makers from various disciplines dealing with this complicated matter.

This paper examines the redevelopment of former gold mining land in Johannesburg for affordable and middle-income housing. For the purpose of this paper, housing in this price range is defined as costing between R80 000 and R200 000 per unit. The former mining land is close to the downtown area, the main hub of transport in Johannesburg and could provide savings for out-of-pocket costs and time saving for commuting costs as well as better property appreciation. However, the remediation of this land may be costly and, even after remediation, may pose some health risks from exposure to radon. A cost–benefit analysis examined these issues in detail, from the perspective of the home occupant. The conclusions are that the value of the net benefits over a 20-year study period indicated very positive cost–benefit ratios, in excess of five units of benefit for each unit of cost to the potential occupant. This suggests that the affordable and middle-income housing markets would, overall, see the area as desirable and that the markets could price the additional risk and might accept housing modified to reduce the potential health risks. The policy implications support the release of former mining land for housing on a careful case-by-case basis.

Despite the importance of the issue, this study does not discuss the moral and ethical issues of building housing on previously contaminated sites that might expose the occupants to some health risks. Having said that, it is nevertheless important to note that the 1972 United Nations Stockholm Declaration on the Human Environment says the protection of human health should be kept in mind as the most important factor when constructing in areas with potential health hazards. Accordingly, if some of the mining dump land is to be developed for housing, extreme care must be taken and engineering solutions adopted to decrease the potential hazards of exposure to radon. These engineering solutions might need to be re-devised to suit Johannesburg conditions and implemented and maintained if the housing projects are to succeed.

A further limitation of this study is that it does not take into account three possible reasons for not building low-income subsidised housing on sites that may be contaminated by radon. The first has to do with the ethical issue of the perceived lack of choice: low-income persons desperate for decent housing might make choices that ignore potential health risks and they may indeed have no real choice in this matter. The second is the need for on-the-ground housing, which is a problem with radon-contaminated land as it increases the potential exposure to the gas (this is discussed in detail below). Finally, the cost of remediating potentially contaminated land would add to the cost of housing development, putting it above the cost of the units that would be built on the radon contaminated site.

This paper is organised as follows. Section 2 reviews the literature on similar international experience and Section 3 presents some background information about radon and remediation. Section 4 describes a survey of 216 respondents in the southwest of the CBD that provided many assumptions for risk tolerance and the financial modelling. The cost–benefit modelling assumptions and results are set out in Section 5 and Section 6 concludes with policy recommendations.

2. LITERATURE REVIEW AND INTRODUCTION TO RADON AND HOUSING

Radon is a natural gas that is colourless, odourless and tasteless but radioactive (Walsh, 2001; Canada's National Occupational Health & Safety Resource, 2005). It results from the decay of radium over the years (Canada's National Occupational Health & Safety Resource, 2005). Some areas, particularly those where heavy metals are mined, have naturally high levels of radon (Canada's National Occupational Health & Safety Resource, 2005). Radon gas is dangerous to human health if it is breathed in continuously over a long period (around 20 years) in a confined area (Walsh, 2001). Gold and uranium are both alluvial heavy minerals and are found together in some mining areas such as Johannesburg (Industrial Disease Standards Panel, 1987). In the Johannesburg mining areas radon gas lingers even after the mine dumps have been removed.

There are several engineering and design solutions for making radon less dangerous in housing (Rydock et al., 2001). One engineering solution, along with good ventilation, is to ensure that residences do not have basements or any ground floor enclosed areas (Rydock et al., 2001). This means that housing consisting of walk-ups of three or four storeys with ground level parking, residential space situated above commercial space, townhouses with open tuck-under garages and similar configurations will present a much lower risk of cancer and other long-term problems. In addition, intrusion into the ground in the form of gardening and utility servicing is undesirable and needs to be carefully managed and monitored.

Engineering solutions vary from country to country. In some European countries, such as the UK and Norway, a radon-proof membrane is installed under the dwelling unit and this has been found sufficient in most cases (Denman et al., 2000). In some extreme cases a fan can be used for ventilating the crawl space under the membrane if it is suspected that the membrane might leak or as an extra precaution or where a membrane cannot be installed or where radon levels are higher (Walsh, 2001).

Besides engineering solutions, there are also institutional control solutions for decreasing human exposure to radon. In the US, radon is considered a known potential hazard and a common approach is to require disclosure of the presence of radon, along with other potential defects, if known, to the seller, in any residential transactions (Simons, 2006:Chapter 3). A study conducted in Norway, a country where radon concentration is naturally prevalent in some areas, found that, after ten years of building houses with preventive measures against radon, the levels in some of the houses are still higher than the accepted concentration levels of 200 Bqs/m^3 (becquerels per cubic metre), about 5.4 pCi/L (picocuries per litre) (Rydock et al., 2002). The researchers concluded that the levels need to be continuously monitored to check whether further reduction might be necessary. In another study on pre- and post-construction levels in dwelling units, the same team established that pre-construction testing of the area is not enough to determine the levels post-construction. Some of the units had levels higher than those of neighbouring units (Rydock et al., 2001). These examples show the importance of continuous monitoring in dwellings built on radon-affected land.

Research conducted on the level of radon gas in dwelling units constructed in Egypt suggested that the levels are higher in bathrooms and kitchens because of the materials used. The area where these dwellings are located is not known for radon concentration: it is the materials, particularly the ceramic tiles and marble and granite used in bathrooms and kitchens, which contribute to the presence of radon in these dwelling units (Ghany, 2006; Ahmad, 2007). Thus, exposure to radon can also be controlled by the selection of building materials.

These studies and findings provide evidence that radon exposure in dwellings is both naturally occurring and possibly related to building materials. In northern countries, where winters are cold and dwelling units are well insulated for heat retention, there must be sufficient ventilation to dispel the radon. In more temperate countries, such as Egypt and South Africa, the recommendation is to increase ventilation to ensure that radon dissipates. In both Egypt and South Africa there is a need for further research to ensure radon levels are monitored and that construction materials do not contribute to the problem. Overall, it is reasonable to conclude from the experience in the US, Norway and the UK that radon is a known and manageable public health issue and not a fatal flaw in housing development.

3. RADON AND CONTAMINATED LAND DEVELOPMENT RELATIVE TO THIS CASE

In South Africa the National Nuclear Regulator is the agency charged with determining the safety of a property for residential or commercial occupation when radon is apparent. The local municipality, province (environmental and procedural) and the Department of Minerals and Energy all have a say in the redevelopment of former mining land. Studies of health risks from radon in South Africa are not readily available, but data from North America and Europe indicate that the risks of contracting cancer, mainly lung cancer, from radon exposure over a lifetime for non-smokers, at levels at or close to the generally accepted safety threshold of 2.7–5.4 (pCi/L), which is equal to about 100–200 Bq/m^3, is between two and seven deaths per 1000 persons exposed (Krewski et al., 2005; World Health Organisation, 2005). If exposure is less than a lifetime or 20 years, death rates are lower.

The assumption for the purpose of this study is therefore that radon exposure is dangerous in enclosed areas, but if the gas is released into the atmosphere (for example by using the ground floor as a ventilated garage) it does not reach sufficient levels of concentration to cause health problems and is not considered harmful. On the basis of the studies cited above, the assumption is that cancer deaths attributable to living in the projects to be constructed in Johannesburg from a lifetime of exposure for non-smokers would be five per 1000 residents at a radon level of 200 Bq/m^3, which is equivalent to about 5.4 pCi/L

(Simons et al., 2006) according to the US Environmental Protection Agency standards. This is a conservative estimate, since a ventilated ground floor should ensure zero or near-zero radon levels on the residential floors above and, consequently, a lower probability of cancer from exposure to radon.

3.1 The redevelopment process for contaminated land sites

Where contaminated mining land is required for housing development a certificate of mine closure is required to conform with Section 43 of the Minerals and Petroleum Resources Development Act of 2002 (Act No. 28 of 2002). This certificate can only be granted once the land in question has been rehabilitated. The application for closure also needs to include an Environmental Risk Report. A closure certificate cannot be granted if the land's environmental impacts and risks have not been addressed. The closure plan must also state what the final land use will be after rehabilitation. Most former mining land is legally classified as such and carries no development or urban zoning rights in its existing state.

Several provisions have to be fulfilled before contaminated land can be developed. The certificate of closure has to be granted before the Gauteng Department of Agriculture, Conservation and Environment can grant a Record of Decision. The National Nuclear Regulator must also provide a statement that the radon levels are within the acceptable limit for the intended use. It is important to err on the side of caution and take into consideration the cost of mitigation, bioaccumulation in garden vegetables and fruit, risk-based corrective action, potential exposure levels, health risks and so on. The National Nuclear Regulator (2005) policies on redevelopment of land provide some guidance. An Environmental Planning and Impact assessment is also required in terms of Section 21 of the Environmental Conservation Act of 1989 (Act No. 73 of 1989). Once the environmental clearances have been granted, the project may present applications for land use to the Johannesburg Planning Authority. An important question here is whether South African buyers interested in affordable housing will accept non-traditional housing products designed to minimise the health risk of building on former mining dumps in order to take advantage of a better location, as buyers have done in similar situations in other countries.

3.2 Remediation and related development cost assumptions

During a study carried out in September and October of 2005, the authors consulted Richard Bennett, Managing Director of iPROP and assumed a remediation cost of R20 per square metre of land, for 20 per cent of the site, to achieve a radon level of 200 Bq/m^3, equivalent to about 5.4 pCi/L, suitable for a commercial site. To achieve 140 Bq/m^3, about 3.8 pCi/L, a level potentially suitable for residential and commercial use, a remediation cost of R20 per square metre of land for 100 per cent of the site was assumed. An additional R1 million for investigation, overruns and so on was included in the cost.

Since the land is located in the Crown Valley area of Johannesburg's mining belt between Soweto and the Johannesburg CBD (as shown in Figure 1), it was assumed there would be adequate infrastructure for sewerage, water, electricity and roads to serve the projects, at a cost that can be absorbed into a normal development scheme, to service residential development on the sites being investigating. It was also assumed that uses could be found for the existing mine dumps (which contain the tailings from previous mining operations, i.e. the waste that remains after valuable material has been extracted), such as for fill under roads, for common areas or for further mining for gold and disposal strategies such as consolidation via slurry to a centralised location outside the development area. Finally, no further net reductions to development costs were considered.

4. SURVEY RESEARCH CONDUCTED IN SOUTHWESTERN JOHANNESBURG

Johannesburg's former mining land is favourably located for housing development because a large portion of home-to-work trips are made by people living in the south of Johannesburg to the CBD or through the CBD to transfer via taxi to their places of work. This study therefore surveyed the willingness of people living in two areas south of Johannesburg to move to better-located areas and live in flats (apartment blocks), i.e. stacked dwelling units, while also facing some known health risks.

A survey of 216 residents of southern Johannesburg was carried out during September and October of 2005. The interviewees were people living at Orange Farm and at Orlando East in Soweto and weekend shoppers at the Southgate and Eastgate malls (Eastgate attracts some shoppers from the south). It is acknowledged that this was a non-random sample of the Johannesburg population. Before the face-to-face surveys were conducted, interviewers were trained, the instrument was pre-tested, a focus group discussion was held and another pre-testing was conducted. This care was necessary because the population to be surveyed had varying degrees of education and clarity was of extreme importance because of the technical nature of some of the material.

The main purpose of the survey was to provide data to generate some key assumptions for the cost–benefit analysis. Among the issues addressed were the mode and cost of commuting and the time taken, the importance of property appreciation, the perceptions of risk and the potential discounts to be obtained when bidding for contaminated property. The survey also included a contingent valuation analysis.

4.1 Characteristics of the survey respondents

The respondents' ages ranged from 20 to over 70 years, with one-third being in the 30–39 years bracket, one-third in the 40–49 years bracket and about one-fifth in the 20–29 years bracket. The median age was 30–39 years. Data on their education level indicated that 31 per cent had graduated from college or even had a postgraduate degree, substantially higher than the Johannesburg population as a whole. The median monthly household income was about R4500 per month, with about 25–30 per cent of the respondents reporting a monthly income of either below R2500 or above R7500. This compares favourably with the general Johannesburg population's average monthly income of between R3200 and R6400 (Statistics South Africa, 2001).

A major issue of concern was the language of the survey. South Africa has 11 official languages, English being the most widely understood and used as a second language (Statistics South Africa, 2001). The survey protocols called for conducting the survey in English unless the respondents expressed a preference for another official language. About two-thirds of the surveys were conducted in English, with the rest mostly in Zulu and Sesotho and a few in Sepedi, Setswana, isiXhosa, Xitsonga and Afrikaans.

The cost–benefit analysis required information about the means of transport the respondents used for commuting. The survey revealed that the average one-way time for the trip to work was 35 minutes, with an average cost of R18 each way. Approximately 35 per cent of the respondents used taxis, 35 per cent used their own cars, 13 per cent walked, 10 per cent took the train, 7 per cent took the bus and a small number took a lift in another person's car. No respondents used a bicycle.

Another part of the survey asked about various risky activities and how the respondents prioritised these. They were asked to place radon and wind-borne mine dust in the context of other risks. Table 1 shows that the respondents rated the dust as a more significant risk than the radon and, compared with other common risks, they rated radon comparatively low.

4.2 Contingent valuation analysis of four housing scenarios

Contingent valuation analysis was used to study the results of four scenarios of housing based on combinations of two types of location and two types of environmental risk, as shown in Table 2. Contingent valuation analysis has been widely used in North America to estimate the value of non-market goods such as public land. It may include the value of the benefits of improved air and water quality, the increased risk from contaminated drinking water and groundwater, outdoor recreation and protecting wetlands, wilderness areas and endangered species (Carson, 2000). Portney (1994) set out the importance of contingent valuation analysis: this author envisaged the large role it could play in forming public policy. In the past several years it has been extended to apply to measuring environmental damage loss estimates for private property markets in situations where adequate market data do not exist. Simons and Winson-Geideman (2005) provided a summary of recent contingent valuation studies in similar property cases.

As a research method, contingent valuation has well-documented limitations. One is that survey participants may give biased or irrelevant answers to survey questions if they have, for example, a financial stake in the outcome of a legal case or a quarrel with an environmental polluter. These and other issues related to the hypothetical nature of the surveys are considered manageable and this study's methodology stayed within guidelines prescribed in the peer-reviewed literature.

In assessing the impact of the radon and mine dust contamination scenario on respondents, two factors were of key importance. First, the portion of residents not willing to bid on a scenario reflected a loss in market demand. Second, the ratio of maximum

Table 1: Willingness to take risks among the people interviewed

Rank	Score[a]	Type of risky activity and the possible consequences
1	1.31	'Getting very sick from contaminated water'
2	1.37	'Getting HIV/AIDS and dying in ten years'
3	1.44	'Breathing problems from blowing mine dust'
4	1.54	'Getting tuberculosis and being weak and sick'
5	1.62	'Dolomite soils/House collapsing in hole'
6	1.65	'Radon and small cancer risk in 20 years'
7	1.68	'Driving on bald tyres and having a car smash'
8	1.78	'Smoking cigarettes and cancer risk in 20 years'
9	1.80	'Riding in a taxi [a South African low-cost minibus taxi] and maybe having an accident'

[a]On a scale of 1–5, with 1 being the highest perceived risk and 5 the lowest.

Table 2: Results of the contingent valuation analysis

Scenario	
A: uncontaminated property one hour from CBD	
Invalid bids	9
Premium bids	14
Total bids	186 (94.9%)
Average bid	−28.1%
Top half bid	−2.8%
Top quarter bid	4.9%
No bid	1
Total valid bids	196
Grand total	205
B: uncontaminated stacked flat ten minutes from CBD	
Invalid bids	16
Premium bids	17
Total bids	165 (87.3%)
Average bid	−33.7%
Top half bid	−6.1%
Top quarter bid	6.1%
No bid	25
Total valid bids	189
Grand total	205
C: stacked flat with radon	
Invalid bids	12
Premium bids	0
Total bids	141 (73.1%)
Average bid	−53.9%
Top half bid	−31.4%
Top quarter bid	−20.5%
No bid	52
Total valid bids	193
Grand total	205
D: stacked flat with mine dust	
Invalid bids	7
Premium bids	0
Total bids	136 (68.7%)
Average bid	−68%
Top half bid	−50%
Top quarter bid	−36%
No bid	62
Total valid bids	198
Grand total	205

stated bid to the baseline case was interpreted as the potential percentage loss on the property. One minus this ratio reflected the discount. For example, if the bidder's baseline price was R150 000 and their maximum bid was R120 000, then that would be a 20 per cent discount. Because the marginal bidder technique was employed, half or fewer of all bidders were considered in the final results. Certain very low 'bottom fisher' bids, such as those with discounts of up to 99 per cent, could be a type of game playing rather than a serious attempt to bid. A rational seller would not accept such a bid. So, in order to better reflect the market and recognise that top marginal bidders are more likely to bid successfully on a property, only the top half of bidders based on the discount percentage were considered. Further, the data were partitioned again (top quarter bidders) and then analysed using both pools of bidders.

The descriptive results of this analysis show the percentage of respondents who bid on each scenario, as well as the average bids, the top half bids and top quarter bids. These data are shown in Table 2. The baseline property value was R195 000. For scenario A, the uncontaminated property located one hour from the CBD, 95 per cent of the respondents provided a bid. The average bid was discounted by 28 per cent, the top half bid averaged a 3 per cent discount and the top quarter bid was a premium of 5 per cent. Thus, although the remote location was undesirable to most bidders, some actually preferred it.

Overall 87 per cent of the respondents provided a bid for scenario B, the uncontaminated stacked flat located ten minutes from the CBD. The average bid was discounted by 34 per cent, the top half bid averaged a 6 per cent discount and the top quarter bid was a premium of 6 per cent. Therefore, even though about one-eighth of all respondents would not bid on this property, some apparently favoured the location and did not mind the stacked flat (an apartment without direct ground access at ground level), to the point where there is a premium.

In scenario C, the stacked flat property with radon near the CBD, 73 per cent of the respondents provided a bid, meaning that more than one-quarter declined to bid on the property at all. The average bid was discounted by 54 per cent, the top half bid averaged a 31 per cent discount and the top quarter bid was a loss of 21 per cent. Thus, it would seem plausible that there is a market for this type of property and that discounts would be in the 20–30 per cent range, at least initially. This is the most relevant finding that was taken forward to the cost–benefit analysis.

In scenario D, the stacked flat with wind-borne mine dust near the CBD, 69 per cent of the respondents provided a bid, meaning that just over 30 per cent declined to bid. The average bid was discounted by 68 per cent, the top half bid averaged a 50 per cent discount and the top quarter bid was a loss of 36 per cent. These can be viewed as the existing discounts attributable to wind-borne mine dust for sites developed near mine dumps. This also reflects the losses to property values for areas near existing mine dumps, such as the Diepkloof area of Soweto.

The following section describes the cost–benefit analysis, applying these assumptions from the perspective of the householder.

5. SOCIAL AND ECONOMIC COST–BENEFIT ANALYSIS

A cost–benefit analysis is a well-recognised technique and can be used to advise the debate about appropriate public and subsidy policy for ventures that have differing benefits and costs over a long period. This study followed an established, peer-reviewed methodology for cost–benefit analysis for housing problems (Simons & Sharkey, 1997; Simons et al., 2003), radon exposure in housing (Colgan & Gutiérrez, 1996) and decisions to improve the quality of drinking water (Vitaliano, 2003).

It also followed a well-accepted method of using the present economic value of human life in the calculations. The method is a variant of the discounted future earnings approach, with base earnings adjusted upward to avoid a strict labour market valuation of wages (Gramlich, 1998:67–8). This approach is consistent with other methods that have been devised to calculate the economic value of human life (Conley, 1976; Dorman, 1996). The approach selected is commonly used for litigation and other matters.

A cost–benefit analysis was conducted to compare potential mine dump sites redeveloped as housing in the Crown Valley area with a control location in the south and southwestern parts of Johannesburg. Figure 1 shows the general location. The project also considered a representative 20-hectare development site in the Crown Valley and modelled this site against the control location in terms of the following benefit factors: (1) out-of-pocket costs of commuting time, (2) opportunity cost of commuting time at prevailing wage rates and (3) property appreciation. The following costs were also modelled: (1) health issues leading to early death from radon exposure and (2) land remediation.

The costs of remediating the land to acceptable levels of radon contamination will be considered as part of the project costs rather than a cost to the developer. The cost–benefit ratios for the 20-hectare property and per unit were then calculated in order to provide a ratio of benefits to costs. A monthly equivalent breakdown for the same figures was also provided.

The cost–benefit analysis considered both benefits and costs to residents over a 20-year holding period. The benefits through to the end of 2025 were modelled. The health risks were modelled though to 2028 and it was assumed that the remediation costs would be incurred immediately. The present value of the net benefits (after deducting costs) was compared to the cost requirements of remediation and any potential subsidy.

The case study areas in the Crown Valley were compared to the baseline (control) areas of Orlando East and Orange Farm, which were used as examples of market areas that potential buyers or occupants might come from. Survey data from these areas were collected and used for the analysis.

The cost–benefit analysis was considered from the perspective of the occupant household. A parallel analysis could consider government expenditures (see for example, the Aucamp & Moodley (2002) case study of transport costs in eThekwini): this was left for future research. To conduct the analysis, a generic 1000-unit project was created on 20 hectares with a mix of residential uses, none of which were houses on slabs at ground level. Three plausible schemes were developed with different assumptions and, in addition, there was a worst-case scenario fourth scheme for comparison purposes. The assumptions that all four schemes shared were as given in the following sub-sections.

5.1 The property and built-up area

1. There are no purely commercial uses.
2. This is a 1000-unit residential project.
3. There is a maximum of four storeys of walk-ups.
4. The project covers 20 hectares and is a mix of clusters and townhouses with ground floor garages, residential over commercial space and stacked flats with open/ventilated ground-floor garages.
5. There are no houses on slabs.

6. The living areas of the units range from 55 to 85 square metres.
7. There is sectional title ownership.
8. The price range of the units is between R150 000 and R400 000.
9. The project begins construction in 2007 and is absorbed by the market by 2010.
10. The project receives the appropriate governmental environmental and planning approvals.

5.2 The factors involved in radon-related health problems

1. There are 4.5 persons per household.
2. It is assumed that any additional cancer deaths are caused by exposure to radon while in the home.
3. The resident moves in at age 30 years and lives there until age 50 years. Those who die from radon exposure do so at age 53 years, losing 18 years of life.
4. The value of a human life lost today would be R2.7 million.
5. All other factors potentially causing death are held constant.

5.3 The commuting analysis

1. Residents earn R30 per hour.
2. They commute to the Johannesburg CBD by taxi.

5.4 The final general assumptions for conducting the discounting procedures

1. The financial inflation rate is 5 per cent per year.
2. Residents retain the house until 2025 then move on.
3. The subject householder has a personal discount rate of 11 per cent per year.

5.5 Development scenarios

These included the following assumptions.

1. Scheme 1: a short distance between the control area (Orlando East) and the case area, a low property appreciation rate difference (2 per cent), an average unit value of R300 000, a high potential death rate from cancer (five per 1000) and inexpensive remediation for the 20 hectares (R2 000 000) to 200 Bq/m^3, about 5.4 pCi/L.
2. Scheme 2: a short distance between the control area (Orlando East) and the case area, a moderate property appreciation rate difference (4 per cent), an average unit value of R250 000, a low potential death rate from cancer (two per 1000) and very expensive remediation for the 20 hectares (R10 000 000) to 140 Bq/m^3, about 3.8 pCi/L.
3. Scheme 3: a long distance between the control area (Orlando East) and the case area, a higher property appreciation rate difference (7 per cent), an average unit value of R200 000, a low potential death rate from cancer (2 per 1000) and expensive remediation for the 20 hectares (R5 000 000) to 140 Bq/m^3, about 3.8 pCi/L.
4. Scheme 4: a short distance between the control area (Orlando East) and the case area, a very low property appreciation rate difference (1 per cent), an average unit value of R200 000, a very high potential death rate from cancer (10 per 1000) and very expensive remediation (R15 000 000) to 200 Bq/m^3, about 5.4 pCi/L. As this is the worst-case scenario, the assumptions are not realistic. It was designed to demonstrate the

potential net benefits to residents when all the assumptions are skewed towards a negative result.

5.6 Results of the cost–benefit analysis

Tables 3–6 show the results of the cost–benefit analysis. All the figures reflect the present values for the 1000-unit project over the entire study period. They are therefore an 'apples-to-apples' analysis with respect to the time value of money. Using scheme 1 (Table 3) as an example, the present value of the out-of-pocket savings to the householder (between the control area (Orlando East) and the case area) for commuting over the study period is R14.7 million and the saving for the opportunity cost of time lost commuting is R31.5 million. The benefit to the households from property appreciation is R45.3 million and the overall benefits are R91.5 million. This works out to R91 500 per household. On the cost side, early death from radon would have present value costs to householders of R15.2 million. The remediation costs for the project are assumed to be R2 million. The total costs are R17.4 million or R17 200 per unit.

The overall benefits exceed the costs by R74.2 million or R74 200 per unit. The cost–benefit ratio is 5.3 units of benefit for every one unit of cost. Since the cost–benefit ratio is positive, the trade-offs analysed in the project are considered desirable from the householders' point of view. When evaluated on a per month basis, the net benefits (after considering costs) reflect the equivalent of 3.9 per cent of household income.

For the sake of brevity, the results for the other scenarios are summarised briefly. The details are available in Tables 4–6. For scheme 2 the total net benefits (after consideration of costs) are positive at R121.6 million, which is equivalent to R121 600 per

Table 3: The cost–benefit for scheme 1[a]

	Present value for 20 years (R)	Per unit/month	Monthly income (%)
Net benefits			
Commuting time: out of pocket saved	14 698 367	61	0.8
Commuting costs:work time saved	31 496 500	131	1.6
Housing appreciation	45 261 961	189	2.4
Total calculated benefits	91 456 828	381	4.8
Total benefits per dwelling unit	91 457	–	–
Costs			
Early death from disease	15 245 746	64	0.8
Additional site prep (remediation)	2 000 000	8	0.1
Total calculated costs	17 245 746	72	0.9
Costs/dwelling unit	17 246	–	–
Net benefits less costs	74 211 082	–	–
Net benefit less costs/unit	74 211	309	3.9
Cost:Benefit ratio	5.3	–	–

[a]Scheme 1: townhouses and stacked flats, prices R250 000–400 000, Orlando control area, 1000 units, 4500 people and R8000 per household per month.

Table 4: The cost–benefit for scheme 2[a]

	Present value for 20 years (R)	Per unit/month	Monthly income (%)
Net benefits			
Commuting time: out of pocket saved	14 698 367	61	0.8
Commuting costs: work time saved	31 496 500	131	1.6
Housing appreciation	91 509 521	381	4.8
Total calculated benefits	137 704 388	574	7.2
Total benefits per dwelling unit	137 704	–	–
Costs			
Early death from disease	6 098 298	25	0.3
Additional site preparation (remediation)	10 000 000	42	0.5
Total calculated costs	16 098 298	67	0.8
Costs/dwelling unit	16 098	–	
Net benefits less costs	121 606 090	–	–
Net benefit less costs/unit	121 606	507	6.3
Cost:Benefit ratio	8.55	–	–

[a]Scheme 2: townhouses and stacked flats, prices R200 000–300 000, Orlando control area, 1000 units, 4500 people and R8000 per household per month.

unit. The cost–benefit ratio is 8.55:1. This reflects a net benefit of 6.3 per cent of monthly household income (see Table 4).

For scheme 3, which uses a more distant control group and more aggressive property appreciation assumptions, the results are even more positive. The total net benefits

Table 5: The cost–benefit for scheme 3[a]

	Present value for 20 years (R)	Per unit/month	Monthly income (%)
Net benefits			
Commuting time: out of pocket saved	43 278 525	180	2.6
Commuting costs: work time saved	92 739 696	386	5.5
Housing appreciation	102 165 821	426	6.1
Total calculated benefits	238 184 041	992	12.4
Total benefits per dwelling unit	238 184	–	–
Costs			
Early death from disease	4 878 639	20	0.3
Additional site prep (remediation)	5 000 000	21	0.3
Total calculated costs	9 878 639	41	0.6
Costs/dwelling unit	9 879	–	–
Net benefits less costs	228 305 402	–	–
Net benefit less costs/unit	228 305	951	11.8
Cost:Benefit ratio	24.11	–	–

[a]Scheme 3: commercial uppers and stacked flats, prices R150 000–250 000, Orange Farm/remote control area, 1000 units, 4500 people and R7000 per household per month.

Table 6: The cost–benefit for scheme 4[a]

	Present value for 20 years (R)	Per unit/month	Monthly income (%)
Net benefits			
Commuting time: out of pocket saved	14 698 367	61	0.9
Commuting costs: work time saved	31 496 500	131	1.9
Housing appreciation	13 738 932	57	0.8
Total calculated benefits	59 933 800	250	3.1
Total benefits per dwelling unit	59 934	–	–
Costs			
Early death from disease	30 491 491	127	1.8
Additional site prep (remediation)	15 000 000	63	0.9
Total calculated costs	45 491 491	190	2.7
Costs/dwelling unit	45 491	–	–
Net benefits less costs	14 442 308	–	–
Net benefit less costs/unit	14 442	60	0.4
Cost:Benefit ratio	1.32	–	–

[a]Scheme 4: commercial uppers and stacked flats, prices R150 000–250 000, Orlando control area, 1000 units, 4500 people and R7000 per household per month.

(after consideration of costs) are positive at R228.3 million, which is equivalent to R228 300 per unit. The cost–benefit ratio is 24.11:1. This reflects a net benefit of 11.8 per cent of monthly household income (see Table 5).

The results for the worst-case scenario, scheme 4, are still positive. The total net benefits (after consideration of costs) are positive at R14.4 million, which is equivalent to R14 400 per unit. The cost–benefit ratio is 1.32:1. This reflects a positive net benefit of less than 0.5 per cent of monthly household income. Given that the benefit-related assumptions in this scenario are implausibly low and the cost assumptions are implausibly high, it can be safely stated that the project has a positive net benefit ratio in all four scenarios (see Table 6).

6. POLICY RECOMMENDATIONS

After looking at the merits of the study, the conclusion that stacked flat apartments, other townhouses with ventilated ground floors and potentially other housing products that do not include houses on slabs at ground level on mine dump sites are tentatively viable, subject to obtaining the appropriate governmental approvals. From a market perspective this was concluded for the following reasons.

1. The cost–benefit ratios are very positive (>5:1).
2. The benefits outweigh the costs for prospective residents.
3. Demand exists for housing at a modest discount: about 20 per cent of the market would pay within 20 per cent of full, unimpaired market value (as per the survey results) (Simons et al., 2006).

The following housing policy recommendations can therefore be made as regards the potential for the mining sites to meet the goals for housing units.

1. There needs to be an incentive programme for the owners of mine dumps to release land for affordable and moderate-income housing. There also has to be coordination between the municipal government and the owners for the most strategic land to be released for beneficial use.
2. Public and private cooperation needs to be established to connect services and roads to the former mining land, especially given the central location of this land and keeping in mind the sensitivity of digging in contaminated land.
3. There is a need to re-zone properties according to the market need and the most beneficial public use, especially in mixed use areas.
4. The National Nuclear Regulator needs to consider the merits of the housing development applications on former mining land, based on the merits of each case.
5. For the purpose of long-term management and preserving environmental quality with environmental and engineering controls, the idea of sectional title ownership needs to be considered, by setting up responsible homeowner groups.
6. The proposed greater Johannesburg mine dump consolidation project, known as Hloekisa, would substantially benefit the communities of Soweto, particularly Diepkloof, which is situated very close to large existing slime dams and mine dumps. The results of the contingent valuation analysis demonstrate that the positive property value benefits of removing the existing slime dams and mine dumps could exceed 30 per cent (Simons et al., 2006).

In conclusion, releasing strategic former mining land for housing is an important national issue. This study has demonstrated that the redevelopment of this land would have adequate market acceptance for affordable and moderate-priced housing, that the potential benefits to prospective residents outweigh the potential costs and that many of the risks associated with these projects are manageable. While the potential risks to health are acknowledged, no viable housing alternatives are either risk- or cost-free. It is the opinion of the authors that the economic benefits from the superior location and consequent convenience, which can be realised every day a unit is voluntarily occupied by an informed resident, outweigh any potential health risk, which could occur many years in the future and can largely be managed by sensible property management practices that have been tested in other countries. Political issues aside, this land could meet part of the nations' housing needs in a location that would benefit residents and also help to integrate the city.

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